Chapter 12

Vitality and cognitive aging

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INTRODUCTION

This project originated from recent interest in the relationship between neurocognitive functioning and physical fitness in the domain of cognitive gerontology. Although the specific nature of the relationship is far from clear, it is often speculated that high levels of physical fitness may be associated with factors such as improved cerebral blood flow, elevations in cerebral metabolism, and increased nutrient supply to the brain. Indeed, there is increasing evidence in support of the hypothesis that the pace of cognitive aging can be slowed by means of exercise that increases aerobic fitness (e.g., Rogers, Meyer, & Mortel, 1990; Shay & Roth, 1992).

The project, which was conducted at the Department of Movement Sciences (MS) of the University of Limburg, examined hypotheses concerning relations between aging, neurocognitive performance, and physical fitness. Several aspects of neurocognitive functioning were assessed; hand-motor system performance (Discrete and Reciprocal Aiming task), selective preparation of a subset of responses (Spatial Precuing task), and eye-hand coordination (Purdue Pegboard task; Lezak, 1995).

In general, whereas a negative relationship was expected between age and neurocognitive performance, a positive relation was expected between physical fitness and neurocognitive functioning. More specifically, it was hypothesized that the negative effects of aging on neurocognitive functioning would be more pronounced in relatively complex, attentional (i.e., controlled) tasks than in relatively simple, automatic tasks (Salthouse, 1988). Moreover, an interaction between age and fitness was expected, indicating that positive effects of physical fitness on neurocognitive performance are more evident in older than in younger adults.

MATERIALS AND METHODS

Subjects

Subjects were recruited from the population of the Maastricht Aging Study (MAAS). Eighty men and sixty-two women participated in one of six age groups (25, 35, 45, 55, 65, and 75 years). All subjects were healthy and without prior history of motor system disorders and had normal or corrected to normal vision. They all were right-handed, with the exception of three subjects.

Materials

Hand-motor system performance. A black, synthetic 30 x 60 cm tablet with two circular copper targets was mounted on a 85 cm high table. Subjects were asked to hold a stylus in a pen-grip fashion in their right hand. Targets and stylus were connected to a MS-DOS AT computer to record movement time. Three target diameters of 4, 12, and 32 mm, resulting in three levels of movement complexity, were used. Movement amplitude was 8 cm in all conditions. Sampling rate was 1,000 Hz. Performance instructions of the discrete and the reciprocal aiming tasks required subjects to move as quickly and accurately as possible. In the discrete aiming task, subjects had to make a discrete movement through the air from the right to the left 'homing-in' target. In the reciprocal aiming task subjects were instructed to tap the stylus repetitively between two identically sized targets for 15 seconds. Each movement condition of the discrete aiming task consisted of two practice and three experimental trials, whereas the reciprocal aiming task consisted of one practice and two experimental trials.

Selective preparation. In the spatial precuing task, subjects had to respond to spatial-location stimuli with discrete responses from the index and middle fingers of both hands. Two precue conditions were distinguished: a hand-cued condition in which the two fingers on either the left or right hand were precued, and an uncued condition in which no useful advance information was presented. Differences in task complexity, that is, in automatic and controlled preparation mechanisms, were addressed by employing a short and long preparation interval (i.e., 100 and 2,000 ms, respectively).

Eye-hand coordination. The Purdue Pegboard task consisted of a board containing two vertical rows of 25 slotted holes above which the pegs were located (Lezak, 1995). Depending on the task instructions, subjects had to place the pegs in the holes with the right hand, left hand, or both hands simultaneously. The resulting three conditions were expected to reflect conditions of low, medium, and high complexity, respectively. Each condition lasted for 30 seconds so that total testing time was 90 seconds. The score was the number of pegs placed correctly.

Physical fitness. Physical fitness was indexed by subjects' maximal oxygen uptake per kilogram bodyweight (VO_2-max in ml/kg/min) that resulted from a submaximal bicycle ergometer test and by subjects' self-reported current and lifetime physical activities on questionnaires. On basis of these measures subjects in each of three age groups (25–35, 45–55, and 65–75 years) were classified as low or high in physical fitness. This classification was used to relate fitness to neurocognitive functioning. All data were subjected to analyses of variance (ANOVA).

RESULTS AND DISCUSSION

Hand-motor system performance

Results regarding the discrete and reciprocal aiming tasks indicated that greater age was strongly associated with slower movement times (discrete aiming task, $F(5,129)=12.37$, $p<.001$; reciprocal aiming task, $F(5,129)=3.57$, $p<.001$). Moreover, for the discrete aiming task, target size exhibited varying degrees of sensitivity to increased age ($F(10,258)=2.26$, $p<.015$; i.e., the smaller the target, the larger the effect of age), but for the reciprocal aiming task the effect of age was independent of target size. Figure 12.1a and 12.1b depict mean movement time as a function of age and target size for the discrete and reciprocal aiming tasks, respectively.

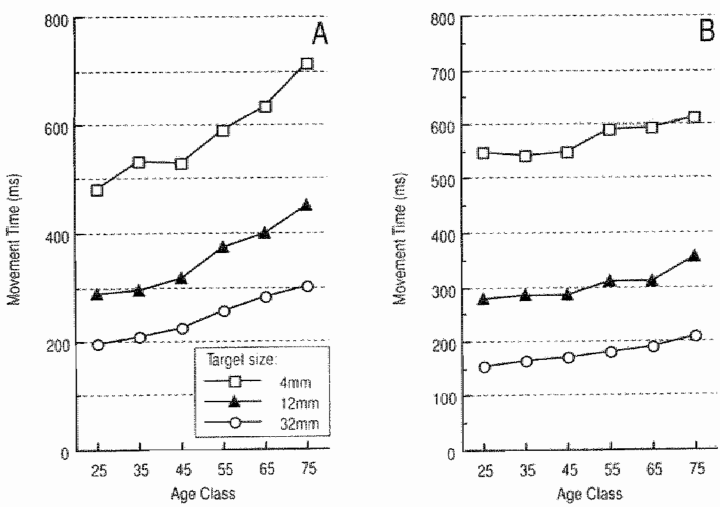

Fig. 12.1.
Movement time (ms) in the discrete aiming task (a) and the reciprocal aiming task (b).

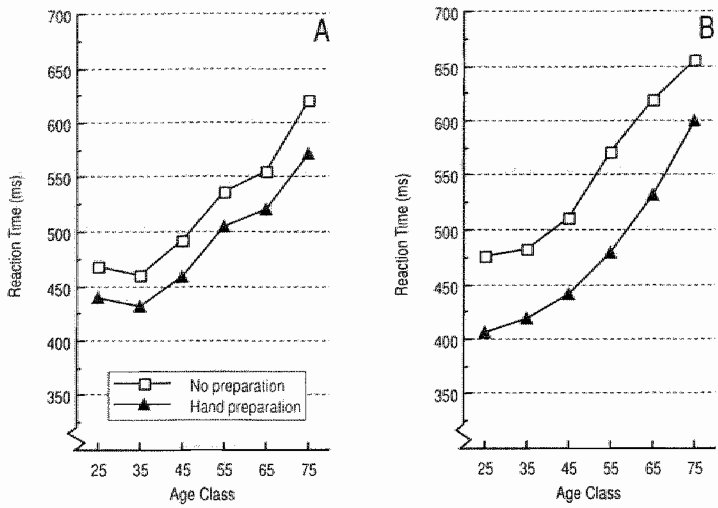

Fig. 12.2.
Precuing Task: Preparation interval 100 ms (a) and 2,000 ms (b).

The outcomes suggest that the underlying control processes of discrete and reciprocal aiming movements are different. It is suggested that reciprocal aiming movements rely less on active, central control processes than discrete movements because the cyclic nature of reciprocal movements invoke a response organization in which component movements are functionally coupled, such that antagonist activity generated during the forward movement is exploited as agonist activity during the reverse movement.

Selective preparation

Results showed that for the short preparation interval of 100 ms the preparation effect (i.e., the difference between the uncued and hand-cued conditions) was invariant with increase in age ($F(5,134)=1.08$, n.s.). For the long preparation interval of 2,000 ms, however, the preparation effect varied markedly as a function of age ($F(5,134)=3.93$, $p<.01$). Figure 12.2a and 12.2b show mean reaction time as a function of age and preparation effect for the 100- and 2,000 ms preparation intervals, respectively.

These findings suggest that fast, automatic preparation is preserved with advancing age, but that the more complex ability to maintain preparation may decline.

Eye-hand coordination

Results revealed main effects of the factors age ($F(5,129)=47.20$, $p<.001$) and complexity ($F(5,129)=282.19$, $p<.001$), and an interaction between

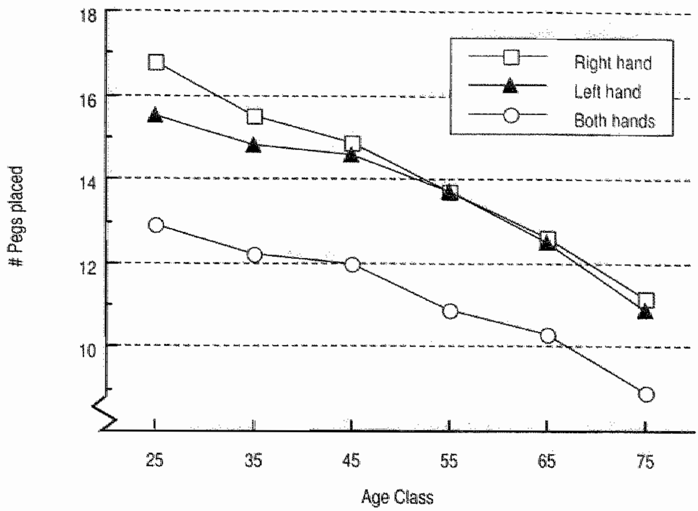

Fig. 12.3.
Purdue Pegboard task: numbers of pegs placed as a function of age.

the age and complexity ($F(10,258)=5.07$, $p<.001$). These outcomes indicate that aging has negative effects on eye-hand coordination and that these effects are more evident in complex tasks requiring two-handed responses than in the less complex one-handed tasks. Figure 12.3 shows performance on the Purdue-Pegboard task as a function of age and complexity.

Physical fitness

Physical fitness operationalized by VO_2-max (in ml/kg/min) significantly decreased as a function of age. Mean VO_2-max for the age groups 25, 35, 45, 55, 65, and 75 were 38, 31, 27, 24, 22, and 14 ml/kg/min, respectively. The scores on the questionnaires revealed no changes as a function of age (F's<1.0). Analyses of the neurocognitive tasks revealed no significant interactions between age and physical fitness (all F's<1.0).

GENERAL DISCUSSION

The results of this project show that advancing age is associated with decreasing neurocognitive performance as operationalized by hand-motor system performance, selective preparation, and eye-hand coordination. Moreover, the results are, by and large, consistent with the complexity hypothesis in that more complex tasks showed greater negative effects of aging on performance. Preliminary analyses suggest a limited role of the variable physical fitness in the relationship between aging and neurocognitive functioning. However, this finding may also be due to the cross-sectional nature of the design, which may have induced cohort effects and self-selection bias. The screening method applied to exclude the possible confounding effect of health status, and a possible selection bias resulting from subjects' consent to bicycle-ergometer testing may have resulted in extra fit older subjects. Consequently, the expected decrease of activity level with higher age and the expected relation between age and fitness might not have materialized.

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